

# The POT-PUFF sign: an angiographic mark of stent malapposition during proximal optimisation

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Coronary bifurcation lesions are frequently encountered in everyday percutaneous coronary intervention (PCI)<sup>1,2</sup> and are associated with a high risk of malapposition and adverse clinical events<sup>3</sup>. To reduce malapposition in the mother branch, the proximal optimisation technique (POT) remains a standard to improve bifurcation PCI<sup>4</sup>. To detect malapposition in the mother branch, we used an angiographic sign based on contrast medium progression through the inflated POT balloon to evaluate coronary opacification and flow, named the POT-PUFF sign. We hypothesised that the progression of contrast medium (PUFF) through the inflated POT balloon (defined as a positive POT-PUFF sign), could better detect stent malapposition than optical coherence tomography (OCT). We investigated the malapposition rate in the mother branch and the diagnostic performance of the POT-PUFF sign in an academic multicentre prospective study.

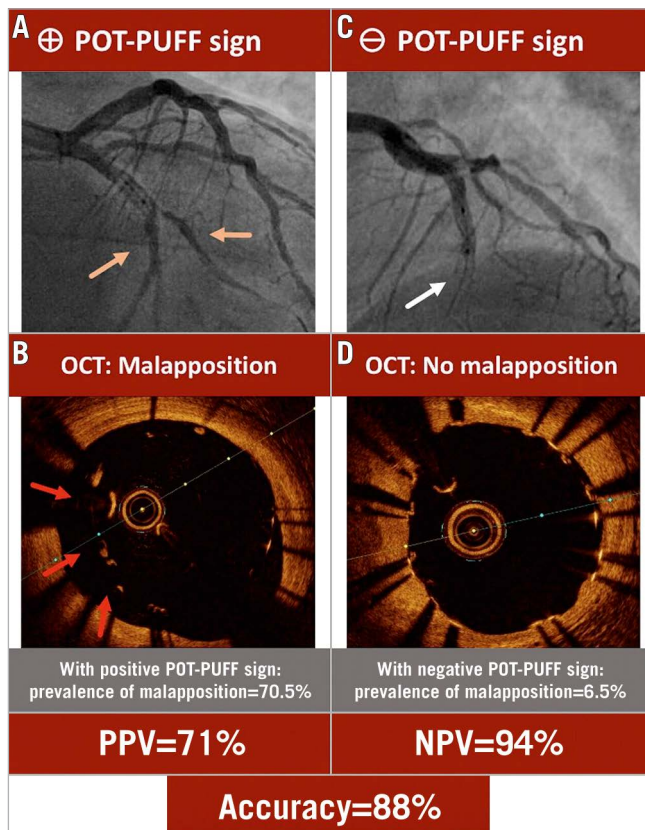
A total of 187 patients with chronic coronary syndrome undergoing non-left main bifurcation PCI were included for post-PCI assessment with POT-PUFF followed by OCT to detect stent malapposition. During the final POT, a contrast medium was injected and its successful progression through the inflated balloon was defined as a positive POT-PUFF sign. We assessed the accuracy of the angiographic sign in identifying stent malapposition as compared to OCT. Strut malapposition was defined as a distance of >200 µm between the strut and the vessel wall, and a distance of >400 µm was defined as severe strut malapposition.

Stent malapposition was defined as strut malapposition more than 1 mm in length.

OCT and POT-PUFF signs were successfully assessed in 187 non-left-main bifurcations. Four patients were excluded because of suboptimal OCT quality which prevented a complete analysis of the POT segment (**Supplementary Figure 1**). In 183 bifurcations, the prevalence of malapposition was 22% for the 200 µm cut-off and 11% for the 400 µm cut-off. The study population, lesion characteristics and PCI strategies are summarised in **Supplementary Table 1** and **Supplementary Table 2**. No adverse events were caused by the POT-PUFF.

From the positive to the negative POT-PUFF sign, the risk of malapposition dropped from 70.5% to 6.5% (**Figure 1**). When evaluated with the cut-off of 200 µm, the sensitivity, specificity, positive predictive value, negative predictive value and accuracy of the POT-PUFF sign were 78%, 91%, 71%, 94% and 88%, respectively. The positive and negative likelihood ratios were 8.5 (4.9-14.7) and 0.3 (0.1-0.4), respectively. The area under the curve (AUC) was 0.84±0.04. For the 400 µm cut-off, the AUC was 0.64±0.05 (**Supplementary Figure 2**). Interestingly, malapposition occurred predominantly in the proximal third of the POT region as compared to the mid or distal third, 16%, 8% and 3% respectively. Of note, the POT didn't completely cover the proximal end of the stent in 55 patients (30%).

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**Figure 1.** The POT-PUFF sign compared to OCT for identification of stent malapposition. A) The progression of the contrast medium through the inflated POT balloon (orange arrows) defines a positive POT-PUFF sign, suggesting malapposition in the POT segment, as confirmed by OCT (B; red arrows). C) The negative POT-PUFF sign shows no progression of contrast medium through the inflated POT balloon (white arrow) and indicates good apposition in the POT segment (D). NPV: negative predictive value; PPV: positive predictive value

Coronary bifurcation PCI is associated with a high rate of complications. The PESTO registry identified strut malapposition as a main cause of stent thrombosis<sup>3</sup>, thus, supporting the need to actively assess malapposition in bifurcation PCI. The lower cut-off of 200  $\mu\text{m}$  also allowed us to consider the milder malappositions more frequently encountered in our daily practice and that are important in bifurcation PCI due to side branch rewiring. The current malapposition depth (>400  $\mu\text{m}$ ) was defined as severe acute stent malapposition<sup>5</sup>. With systematic OCT analysis, we observed frequent malapposition in the POT segment (22%), with half of these being severely malapposed.

The POT-PUFF sign was successfully assessed in all procedures. The effectiveness of the sign was reduced for severe malapposition, which tended to be associated with an uncovered portion of the stent during the POT as the proximal stented area in the mother branch was frequently uncovered (30%). This highlights the importance of covering all of the stented mother branch during POT. With the specificity and negative predictive values both

superior to 90%, the POT-PUFF sign could be relied upon to rule out stent malapposition. In fact, by using the POT-PUFF sign to guide bifurcation PCI, the risk of malapposition in the POT segment drops from 70.5% with a positive POT-PUFF sign to 6.5% with a negative POT-PUFF sign. Of note, few cases of malapposition with negative POT-PUFF signs showed focal malapposition. Thus, focal malappositions may not be detected if the progression of the contrast medium is stopped before or after the malapposed portion. Overall, the POT-PUFF sign is a safe and effective angiographic sign that could be implemented in the current practice to improve detection of stent malapposition in the POT.

We acknowledge several limitations of this study. Firstly, the clinical relevance of the detected stent malapposition can't be evaluated as there was no clinical follow-up. Secondly, stent underexpansion wasn't assessed in the present study. Finally, the POT-PUFF sign only detects malapposition in the POT segment and can only be trusted if the stent in the mother branch is completely covered by the POT. Thus, it could not replace stent enhancement and intracoronary imaging.

The POT-PUFF sign is a cost-free, safe and effective angiographic sign to identify stent malapposition in the POT segment, which occurs in more than 20% of cases.

### Conflict of interest statement

The authors have no conflicts of interest to declare.

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### Supplementary data

**Supplementary Table 1.** Study population characteristics.

**Supplementary Table 2.** Coronary bifurcation lesion characteristics and PCI strategies.

**Supplementary Figure 1.** Flowchart.

**Supplementary Figure 2.** ROC curve of POT-PUFF sign to detect malapposition in the POT area compared to OCT.

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## Supplementary data

**Supplementary Table 1. Study population characteristics.**

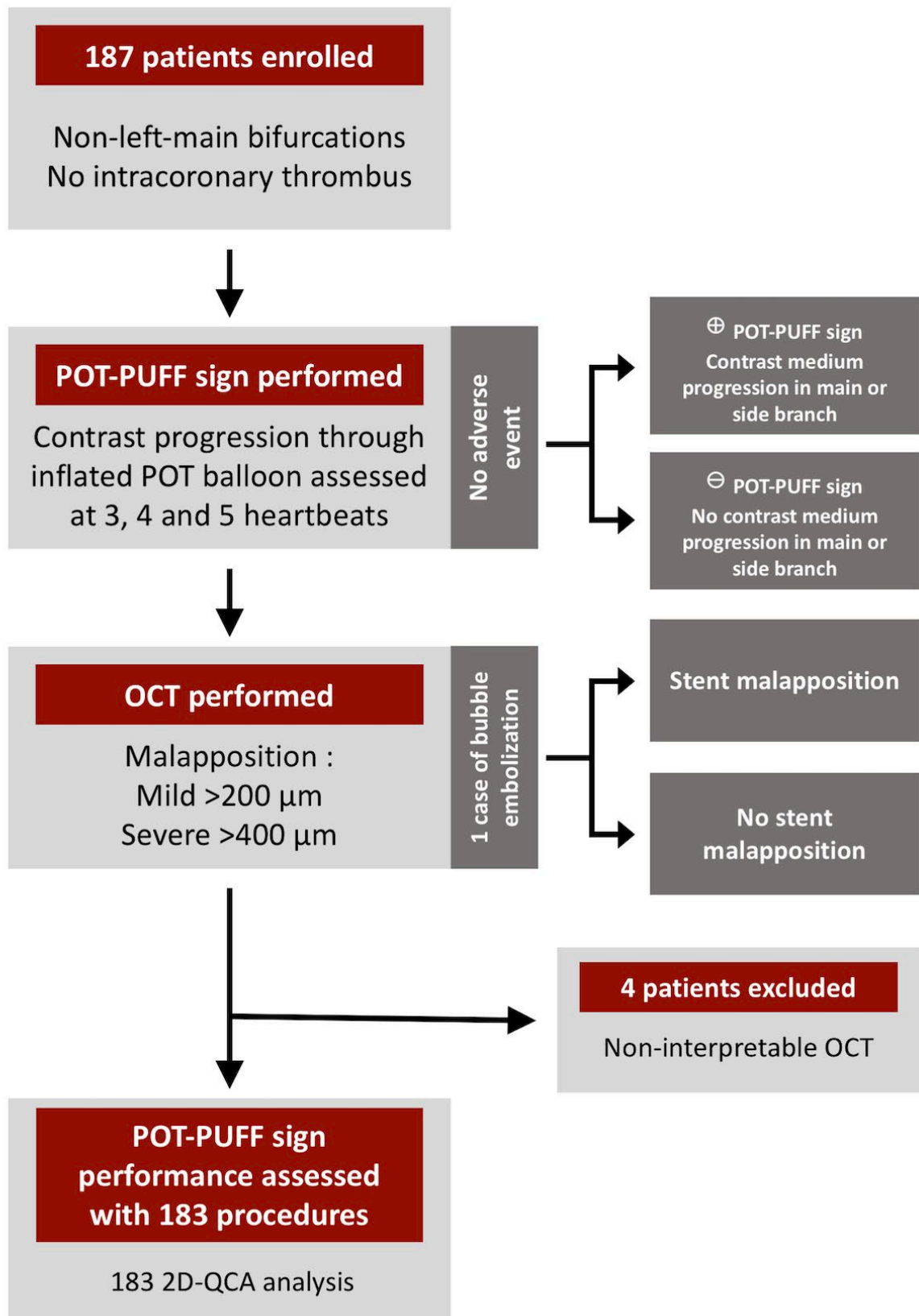
|                                      |            |
|--------------------------------------|------------|
| Age (years)                          | 64 ± 12    |
| Sex (male) %                         | 153 (84%)  |
| Body mass index (kg/m <sup>2</sup> ) | 26.3 ± 4.1 |
| Hypertension                         | 114 (62%)  |
| Dyslipidemia                         | 95 (52%)   |
| Diabetes                             | 43 (24%)   |
| Active smoker                        | 65 (36%)   |
| Former smoker                        | 55 (30%)   |
| Family history of CAD                | 33 (18%)   |
| Renal insufficiency (GFR<60mL/min)   | 15 (8%)    |
| Past history of PVD or PCI           | 11 (6%)    |
| Past history of stroke               | 1 (1%)     |
| LVEF (%)                             | 57 ± 10    |

CAD = Coronary artery disease, GFR = Glomerular filtration rate, PCI = Percutaneous coronary intervention, PVD = Peripheral vascular disease, LVEF = Left ventricular ejection fraction.

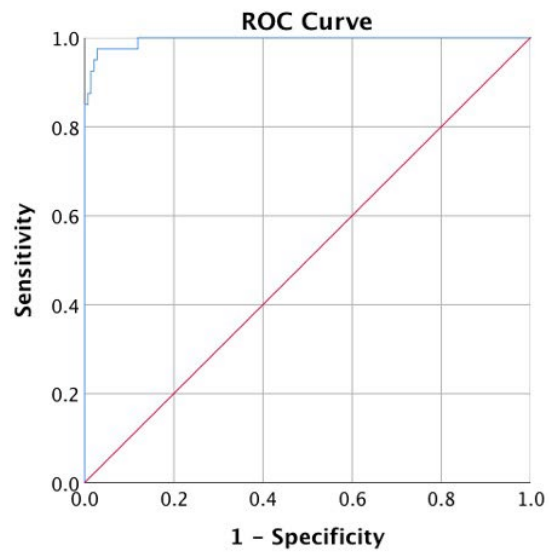
**Supplementary Table 2. Coronary bifurcation lesion characteristics and PCI strategies.**

|   |                        |  |
|---|------------------------|--|
| Dominance   |                        |  |
| Right   | 151 (83%)              |  |
| Left  | 28 (15%)               |  |
| Codominance   | 4 (2%)                 |  |
| Left anterior descending artery – Diagonal branch   | 146 (80%)              |  |
| Left circumflex artery – Marginal branch            | 27 (15%)               |  |
| 1 <sup>st</sup> Marginal – 2 <sup>nd</sup> Marginal | 2 (1%)                 |  |
| Right coronary artery – Posterior descending artery | 8 (4%)                 |  |
| Medina classification                               |                        |  |
| 1-1-1   | 38 (21%)               |  |
| 1-1-0   | 42 (23%)               |  |
| 0-1-1   | 22 (12%)               |  |
| 1-0-1   | 20 (11%)               |  |
| 1-0-0   | 21 (11%)               |  |
| 0-1-0   | 27 (15%)               |  |
| 0-0-1   | 13 (7%)                |  |
| Visual estimation                                   |                        |  |
| Mother branch diameter stenosis (%)                 | 53 ± 29%               |  |
| Main branch diameter stenosis (%)                   | 52 ± 30%               |  |
| Side branch diameter stenosis (%)                   | 41 ± 31%               |  |
| 2D-QCA analysis                                     |                        |  |
| Mother branch diameter stenosis (%)                 | 54 ± 25%               |  |
| Main branch diameter stenosis (%)                   | 51 ± 27%               |  |
| Side branch diameter stenosis (%)                   | 44 ± 28%               |  |
| Mother branch reference diameter (mm)               | 3.4 ± 0.7              |  |
| Main branch reference diameter (mm)                 | 2.7 ± 0.6              |  |
| Side branch reference diameter (mm)                 | 2.2 ± 0.6              |  |
| PCI strategy  |                        |  |
| Provisional stenting                                | 162 (89%)              |  |
| DK Crush or Mini-Crush or Reversed T or TAP         | 21 (11%)               |  |
| Non-compliant balloon                               | 134 (73%)              |  |
| Semi-compliant balloon                              | 45 (25%)               |  |
| POT strategy  |                        |  |
| POT – side – POT                                    | 81 (44%)               |  |
| POT alone   | 65 (36%)               |  |
| Kissing POT   | 37 (20%)               |  |
| POT balloon size                                    |                        |  |
| Diameter  | 3.51 ± 0.46 mm         |  |
| Length  | 10.88 ± 2.87 mm        |  |
| Contrast medium volume                              | 221 ± 68 ml            |  |
| Radiation dose                                      | 34'959 ± 33072 mGy.cm2 |  |

DK crush =  
Double  
kissing crush,  
PCI =  
Percutaneous  
coronary  
intervention,  
POT =  
Proximal  
optimization  
technique,  
TAP = T and  
small  
protrusion,  
2D-QCA =  
2D-  
quantitative  
coronary  
angiography.



Supplementary Figure 1. Flow chart.



**Supplementary Figure 2.** ROC curve of POT PUFF sign to detect malapposition in the POT area compared to OCT.